Introduction to Coastal Engineering

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Objectives

To review for students:

1. **Answer the question: What is Coastal Engineering?**

2. **Introduction to the vocabulary used by coastal scientists and engineers.**

3. **Explain some similarities and differences between the principal US coastal regions: geology, storm risk, etc.**

4. **Provide an overview of important physical processes in the coastal zone.**

References

ER 1105-2-0100, Planning Guidance Notebook

EM 1110-2-1100, Coastal Engineering Manual

***Shore Protection Manual*. 1984. 4th ed., 2 Vol., U.S. Army Engineer Waterways Experiment Station, U.S. Government Printing Office, Washington, D.C.,**

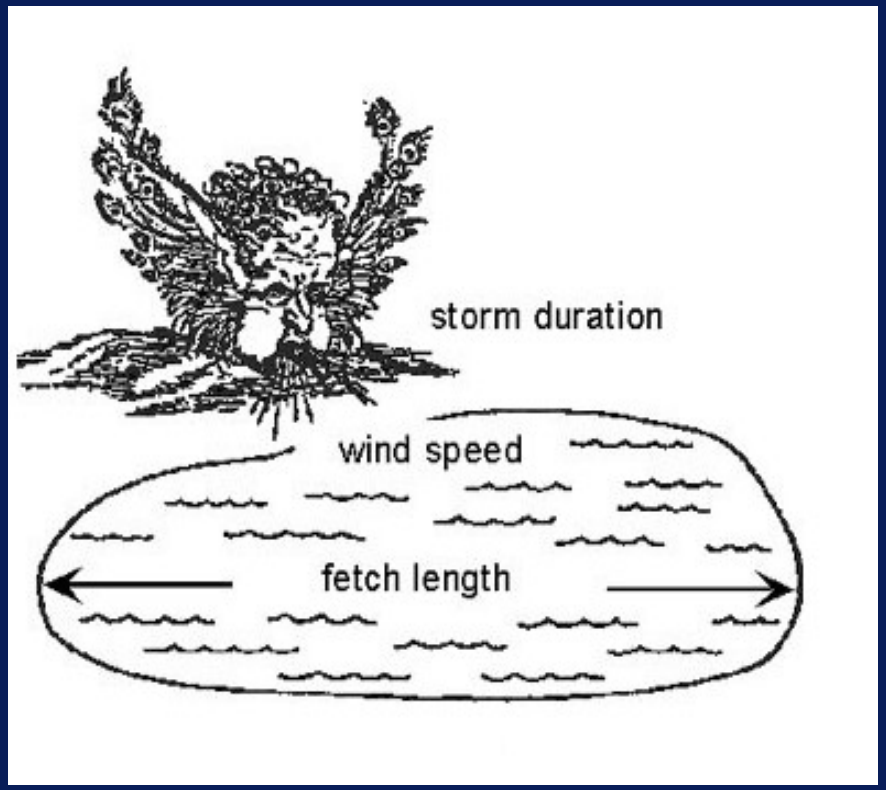
What is Coastal Engineering?

The USACE Coastal & Hydraulics Laboratory defines coastal engineering as: A branch of civil engineering that applies engineering principles specifically to projects within the coastal zone (nearshore, estuary, marine, and shoreline).

The University of Delaware defines coastal engineering as: Coastal engineering is the study of the processes ongoing at the shoreline and construction within the coastal zone. The field involves aspects of nearshore oceanography, marine geology, and civil engineering, often directed at combating erosion of coasts or providing navigational access.

Coastal Engineering Vocabulary

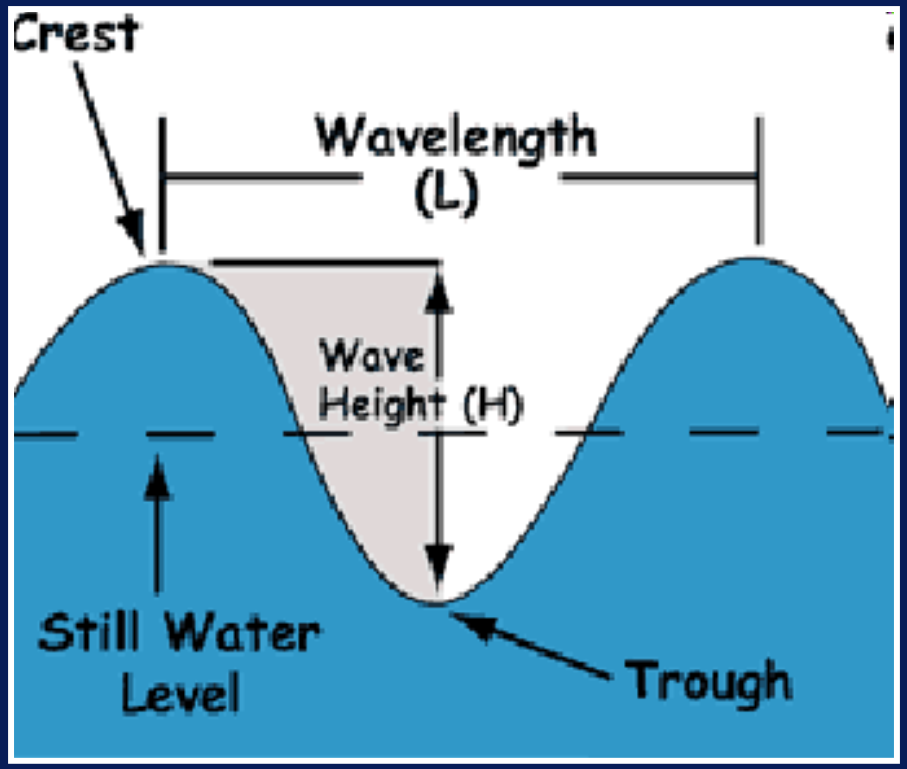
Water Wave - A deformation of the water's surface.



Duration - length of time the wind blows.

Wind speed – How fast the wind is blowing.

Fetch – The horizontal distance (in direction of the wind) over which a wind blows.



Crest - highest point on a wave.

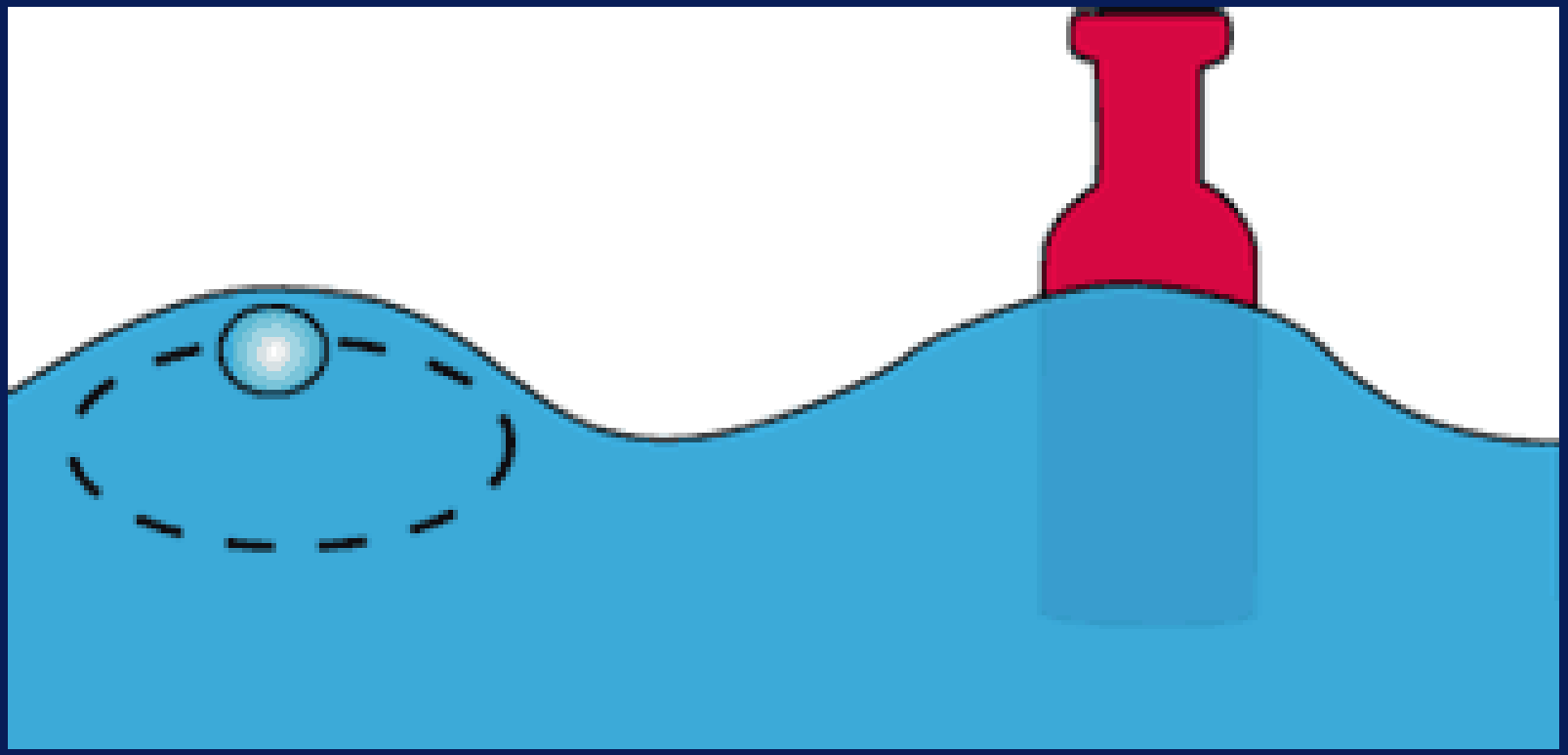
Trough - lowest point on a wave.

Wavelength - horizontal distance, either between the crests or troughs of two consecutive waves.

Wave height - vertical distance between a wave's crest and the next trough.

Wave period - time it takes for two consecutive crests or troughs to pass a stationary point.

FACT – Deep water particles do not move forward with water wave, but instead move in elliptical orbits. Waves are the forward motion of energy, not water!



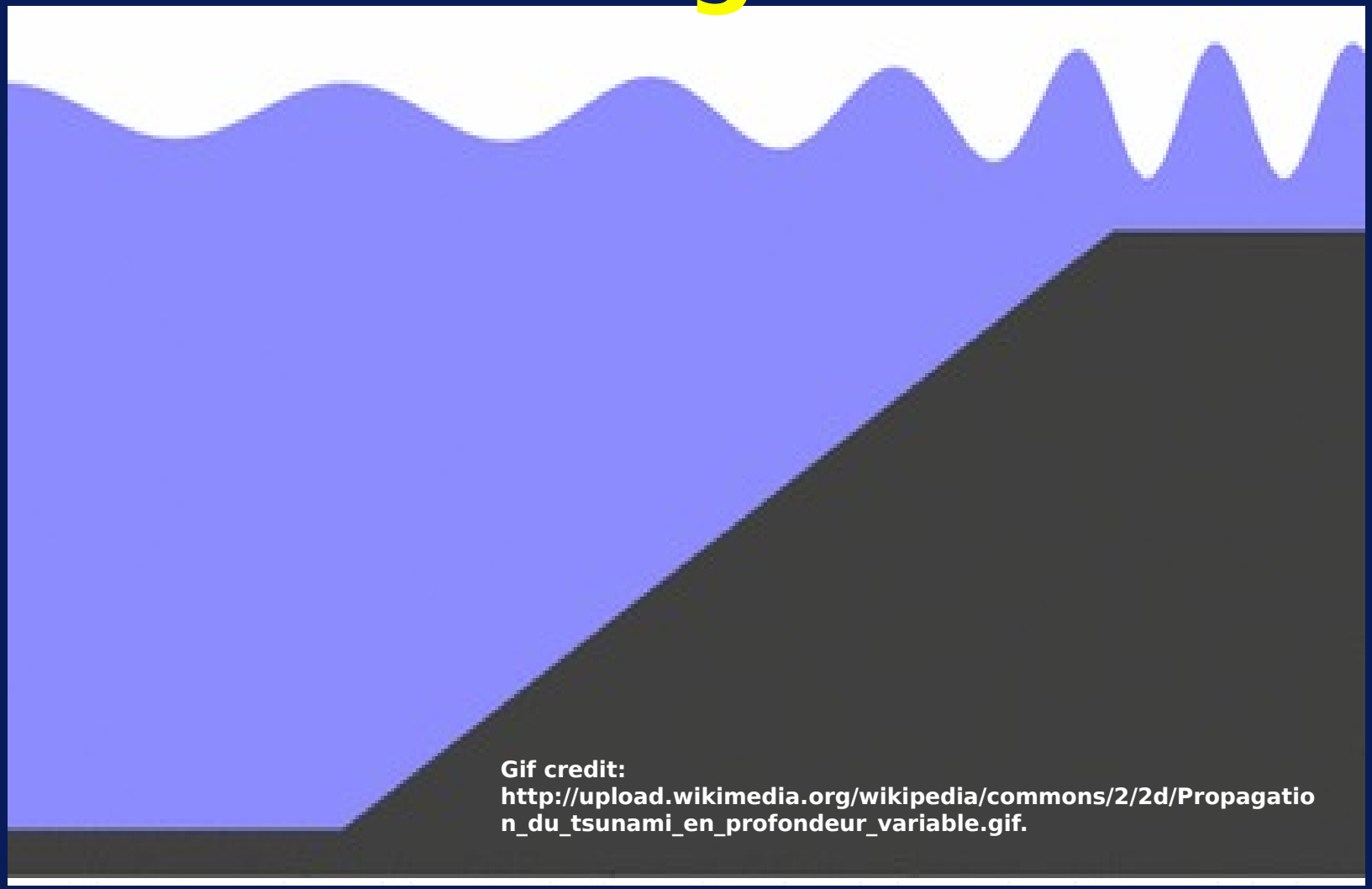
Refracti on

Example of water wave refraction at Allenhurst, Lock Arbour, Asbury Park, 1987.

Diffraction

Photo credit: Fjellanger Widerøe A.S.

Shoaling


Gif credit:
http://upload.wikimedia.org/wikipedia/commons/2/2d/Propagation_du_tsunami_en_profondeur_variable.gif.

Wave Breaking

Wave Run-up

Wave Set-up

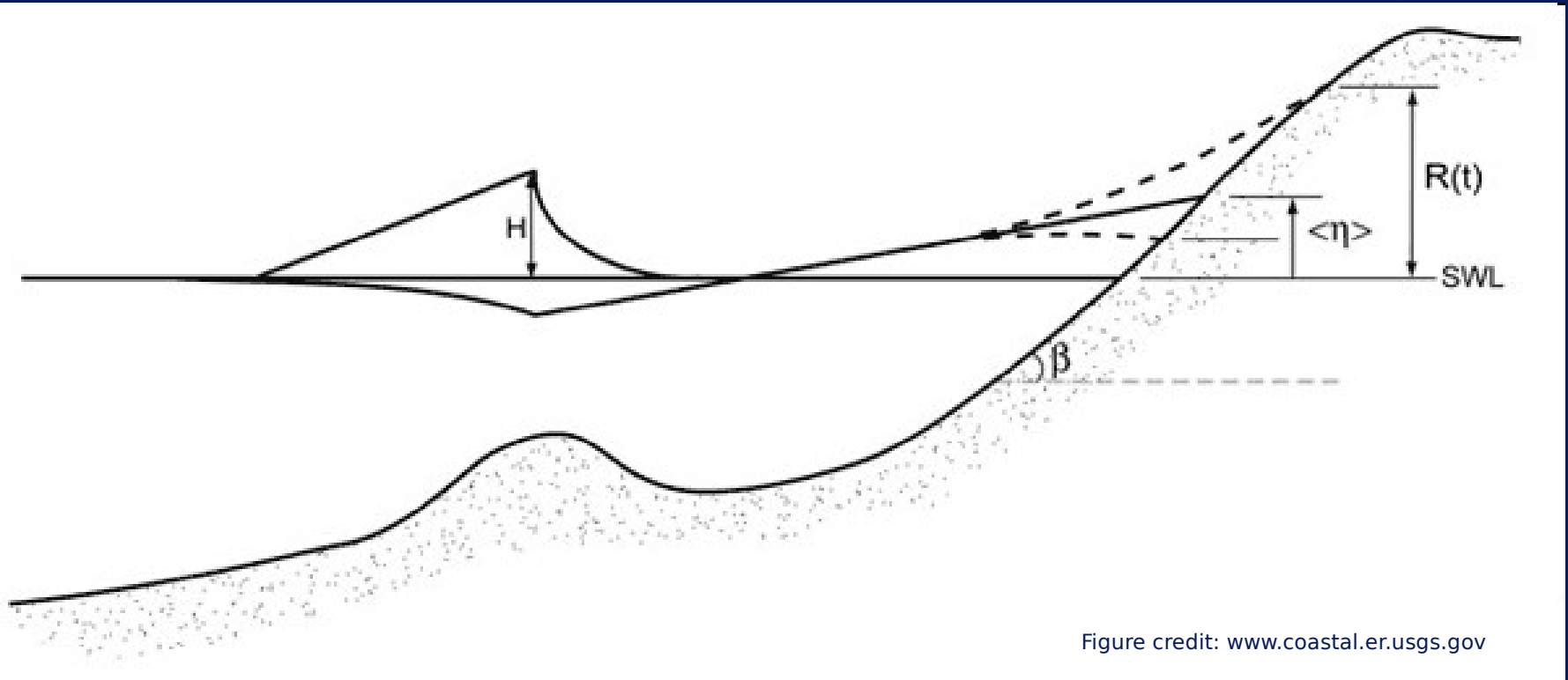


Figure credit: www.coastal.er.usgs.gov

TIDES

- Tides are caused by the gravitational force exerted by both the sun and moon and by the centrifugal force produced by the revolution of the earth .

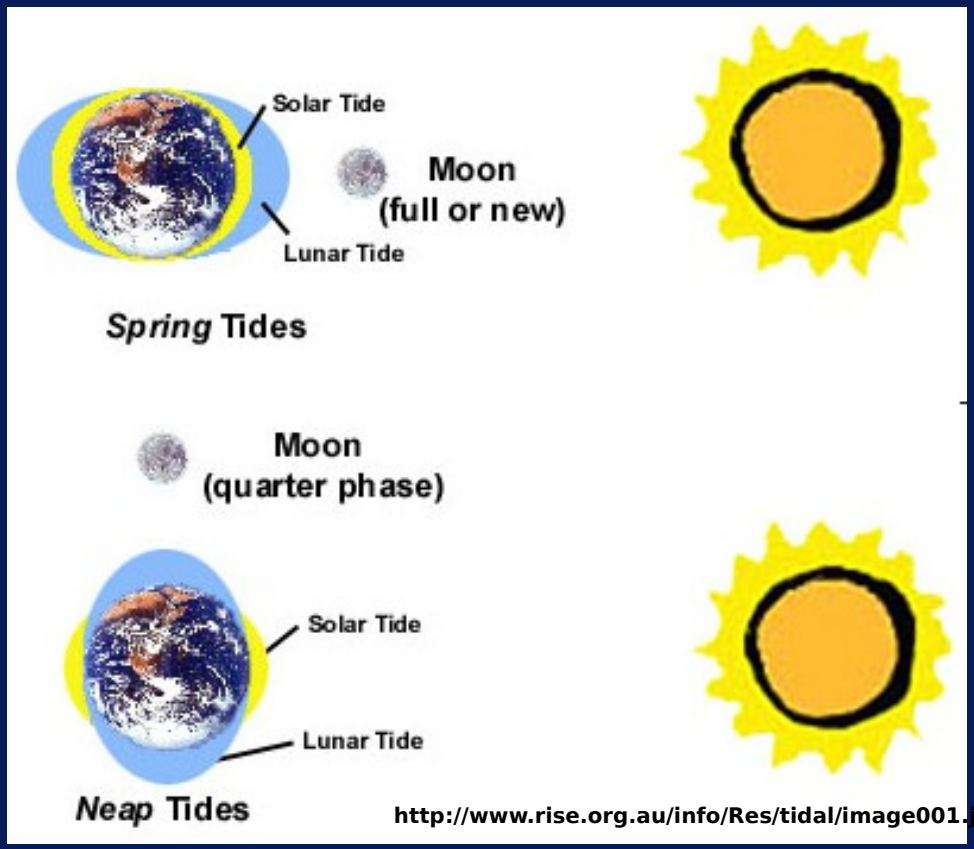
- Normal water levels are tidally influenced.

TIDES

- Two bulges of water – one on the side of the earth facing the moon (and sun) and one on the opposite side.

- The bulges are stationary (relative to the Moon or sun), but the rotation of the earth about its polar axis causes the bulges to move relative to the earth.

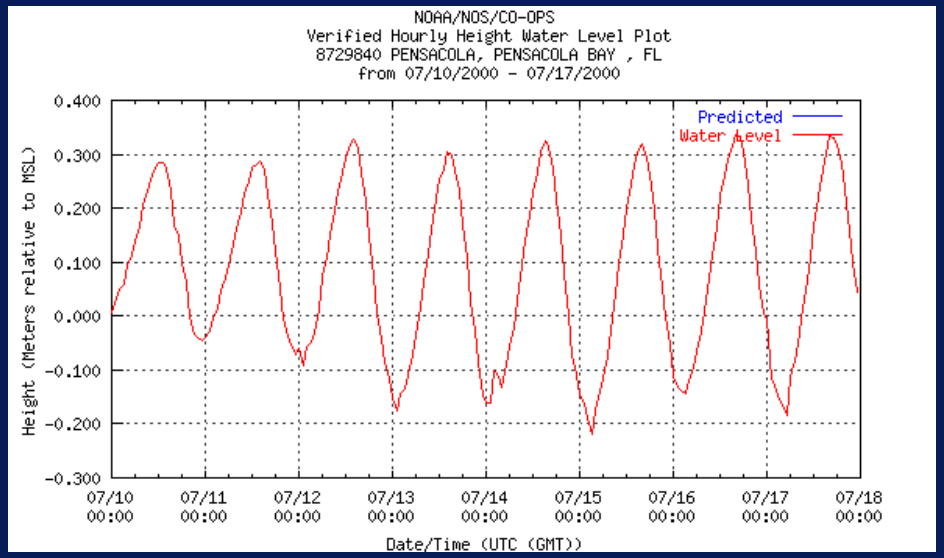
TIDES



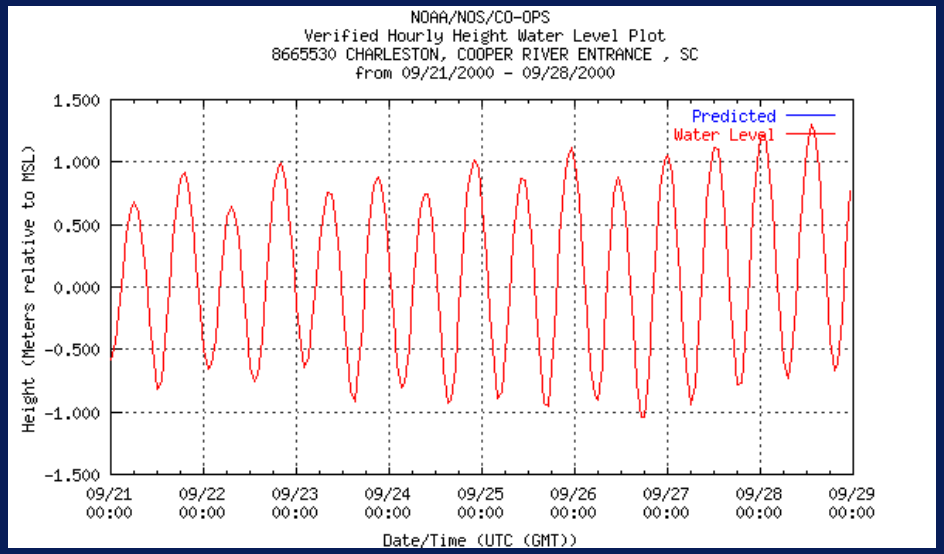
http://www.rise.org.au/info/Res/tidal/image001.jpg

- **Spring tide is when the bulges due to the sun and moon are aligned (full moon and new moon).**
- **Neap tide is when the sun and moon are in quadrature (quarter moon) and thus the respective bulges are not aligned.**

TIDES

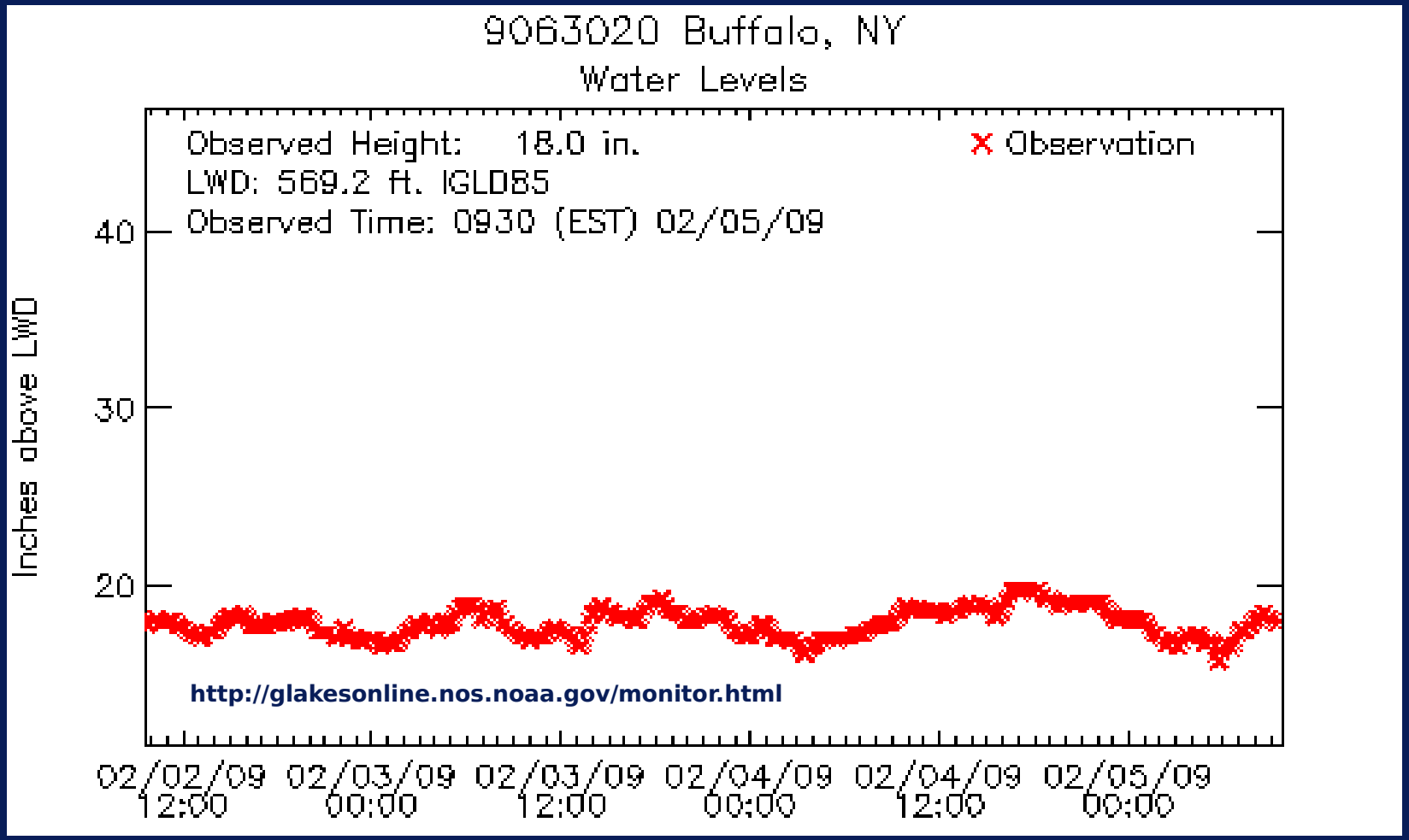


Diurnal Tide – one high and low per day.



Semi-diurnal Tide – two highs and two lows per day.

Do the Great Lakes experience tides?

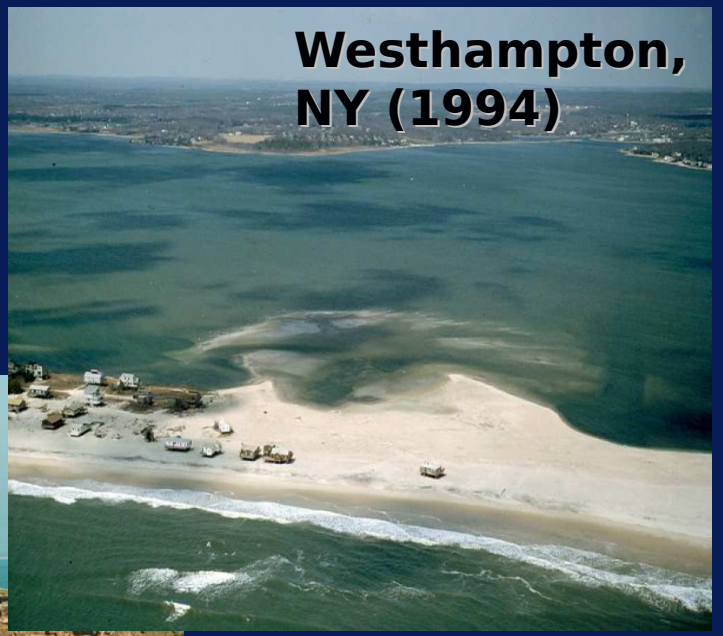


Similarities and differences between the principal US coastal regions

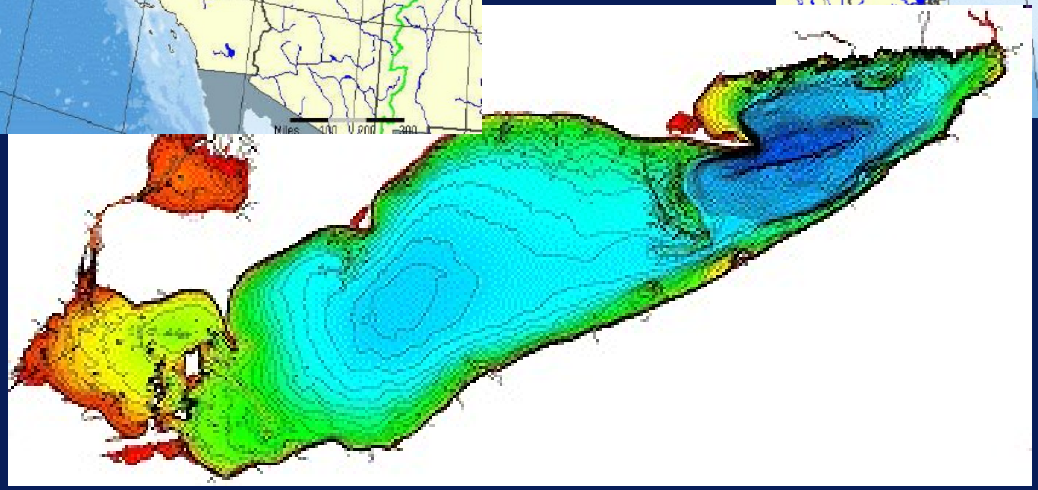
Geology

	Atlantic/Gulf Coast	Pacific Coast	Islands	Great Lakes
Topography	Flat Coastal Plain	Steep Mountains	Volcanic	Continental
Bathymetry	Wide Shallow Shelf	Steep Offshore	Steep Offshore Reefs	Glacier modified

Topography



Bathymetry



Storm Risk

Storm Hazard	Atlantic/Gulf Coast	Pacific Coast	Islands	Great Lakes
Tsunami	Low	High	High	Very Low
Hurricane	High	Very Low	Very Low	Very Low

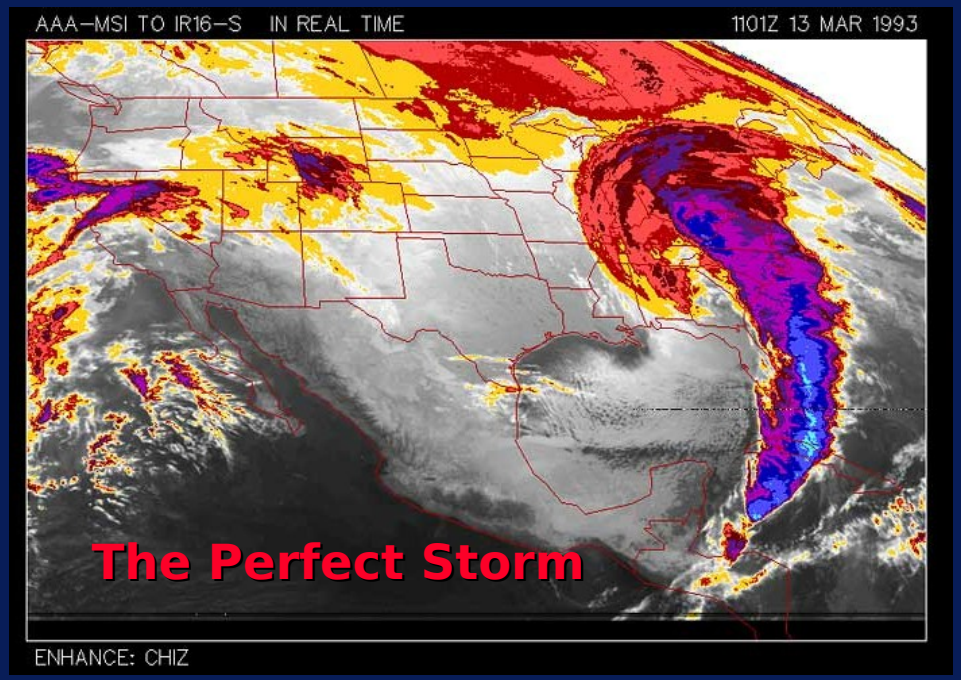
Atlantic/Gulf Coast

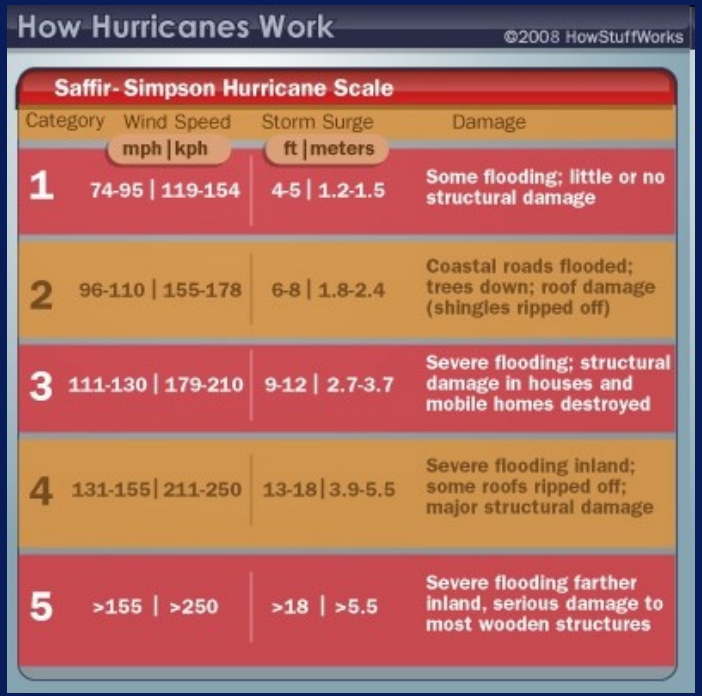
Extra-tropical storm

- Forms outside the tropics.
- Center of storm is colder than the surrounding air.
- Has fronts.
- Strongest winds in the upper atmosphere.

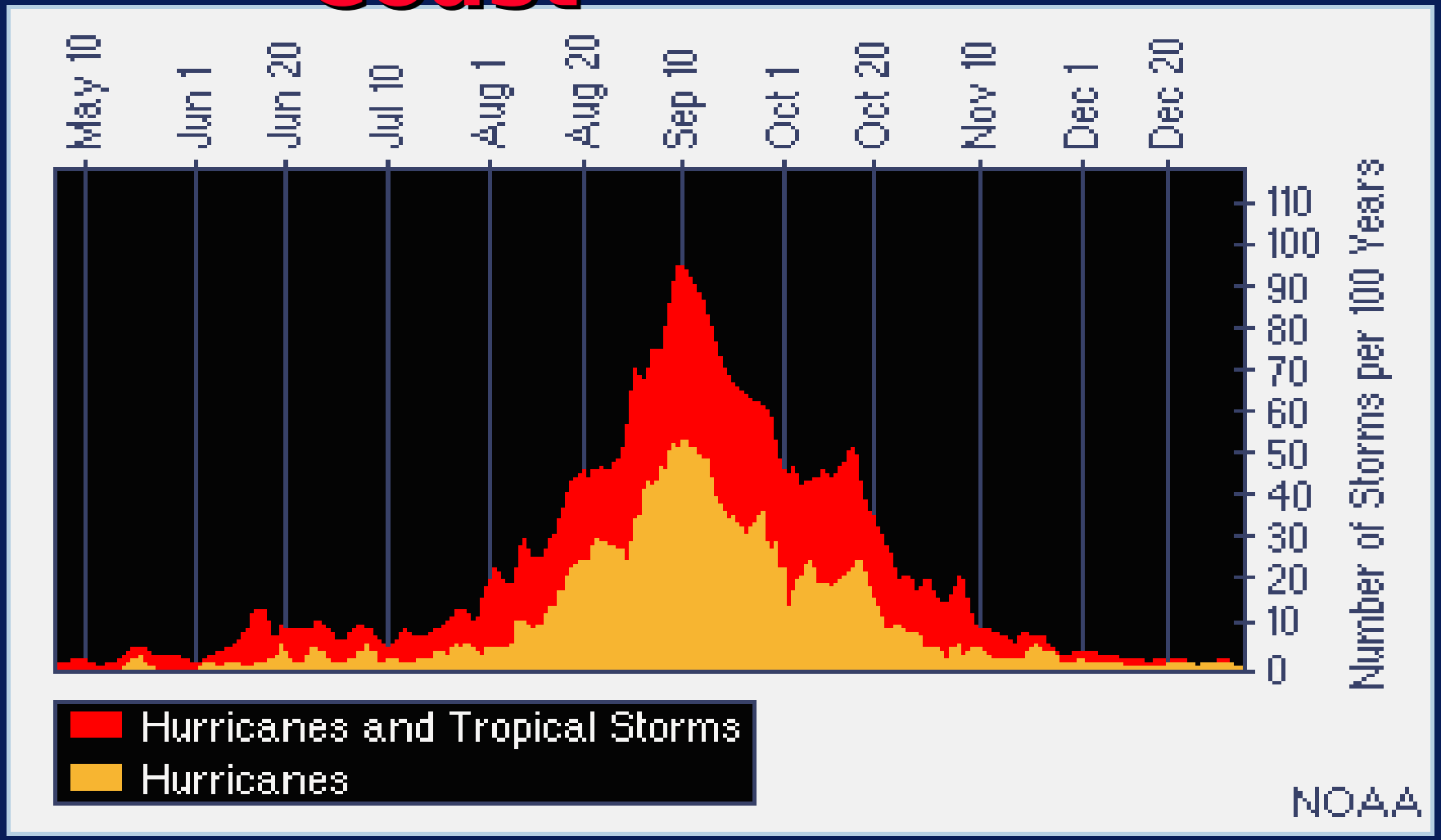
Tropical storm:

- Forms over a tropical ocean.
- Center of storm is warmer than the surrounding air.
- Has no fronts.
- Strongest winds are near the Earth's surface.




How Hurricanes Work
©2008 HowStuffWorks
Saffir-Simpson Hurricane Scale
Category
Wind Speed mph | kph
Storm Surge ft | meters
Damage
1 74-95 | 119-154 4-5 | 1.2-1.5 Some flooding; little or no structural damage
2 96-110 | 155-178 6-8 | 1.8-2.4 Coastal roads flooded; trees down; roof damage (shingles ripped off)
3 111-130 | 179-210 9-12 | 2.7-3.7 Severe flooding; structural damage in houses and mobile homes destroyed
4 131-155 | 211-250 13-18 | 3.9-5.5 Severe flooding inland; some roofs ripped off; major structural damage
5 >155 | >250 >18 | >5.5 Severe flooding farther inland, serious damage to most wooden structures

Atlantic/Gulf Coast



Important Hurricane parameters

1. Central Pressure Deficit
2. Radius of Maximum Wind Speed
3. Forward Speed and Angle of Approach (Quadrant)
4. Storm Surge
5. Timing (Tide)

1. Central Pressure Deficit

Hurricane Floyd

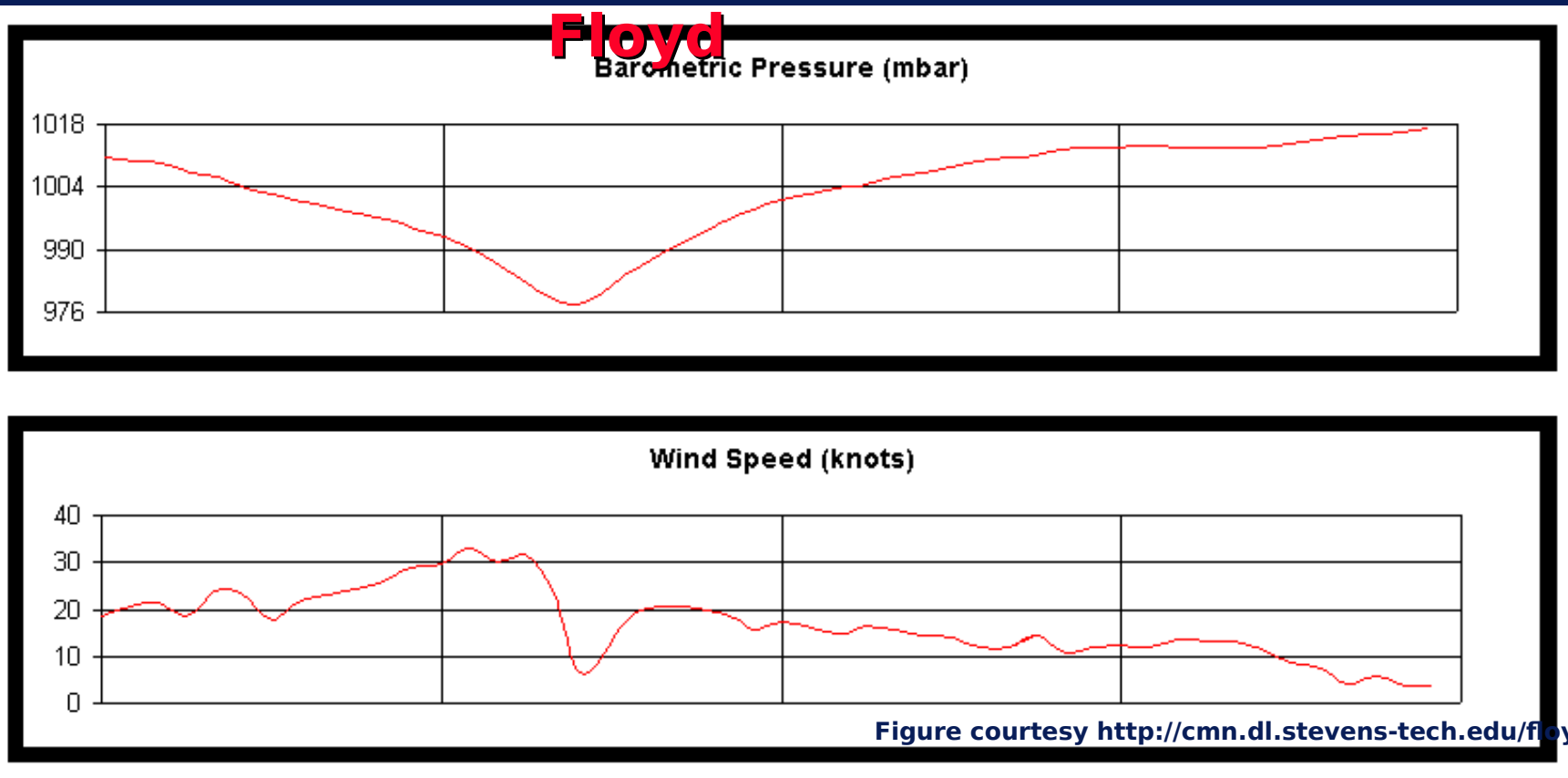


Figure courtesy http://cmn.dl.stevens-tech.edu/floy

2. Radius of Maximum Wind Speed

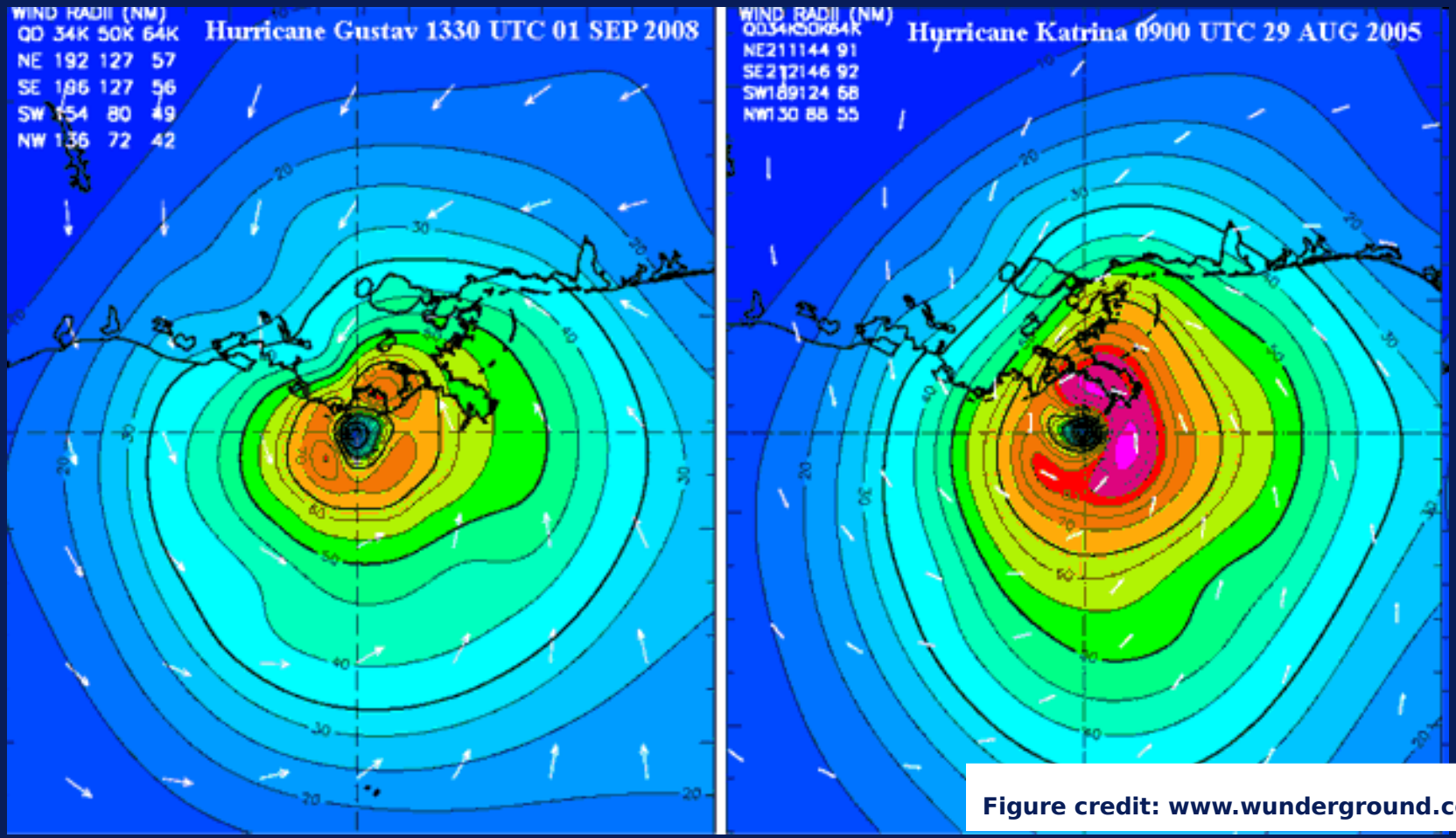
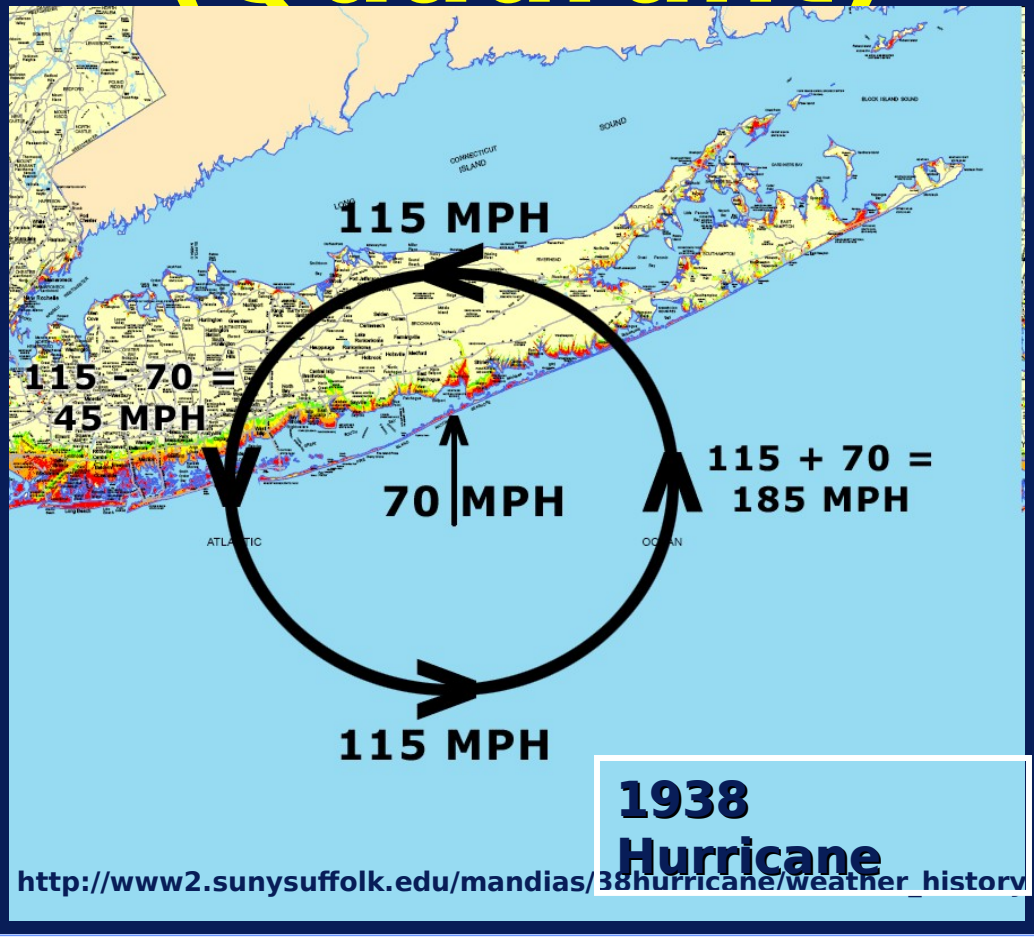


Figure credit: www.wunderground.com

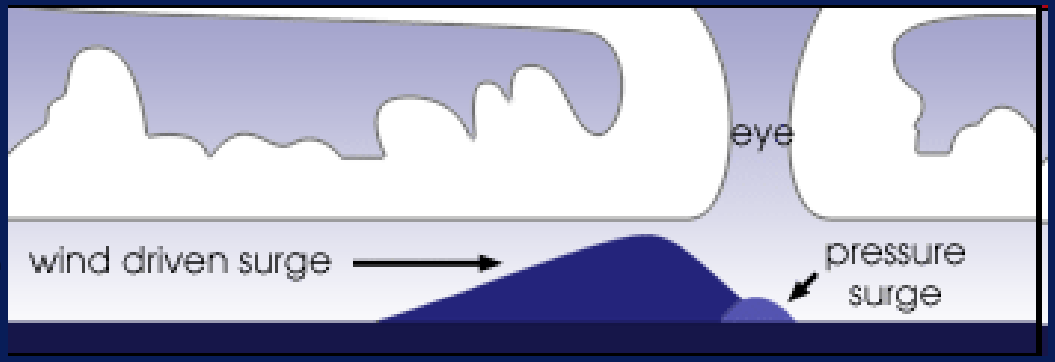
3. Forward Speed and Angle of Approach (Quadrant)



4. Storm Surge

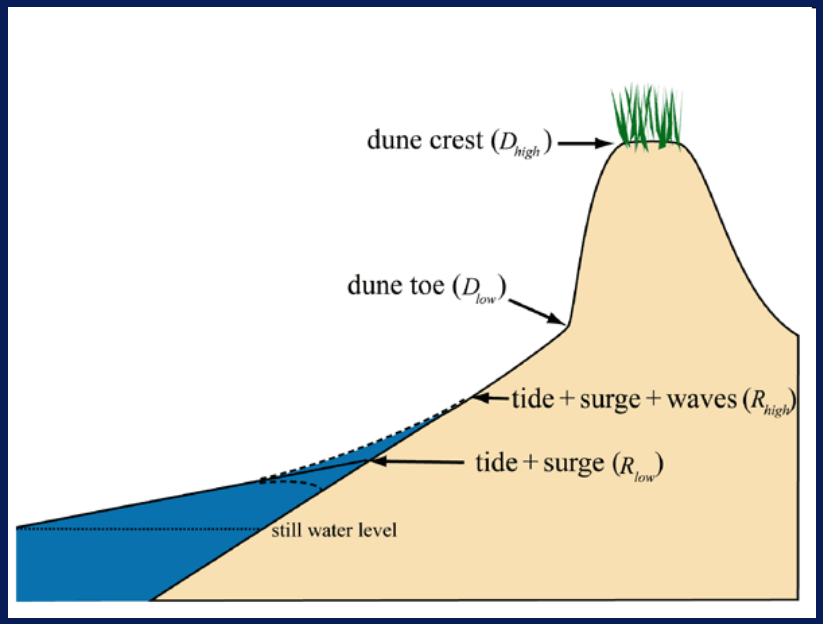
Components:

A. Pressure surge



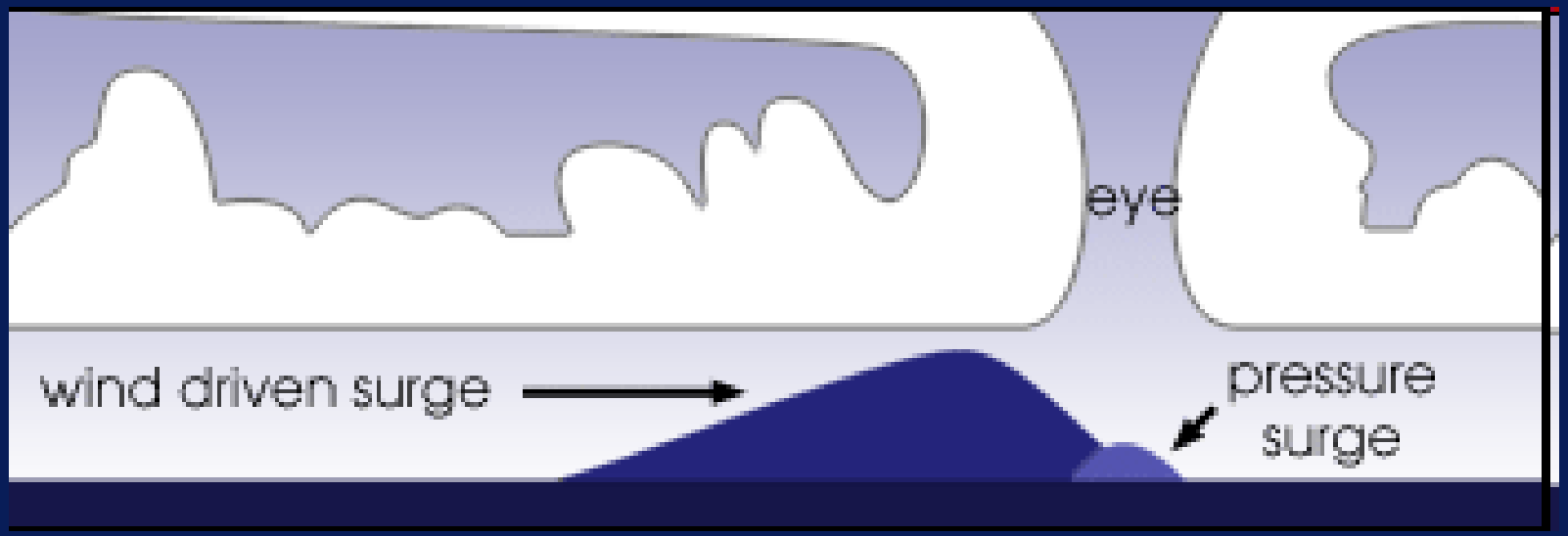
B. Wind surge

C. Wave setup



http://coastal.er.usgs.gov/hurricanes/impact-scale/images/fig1LG.gif

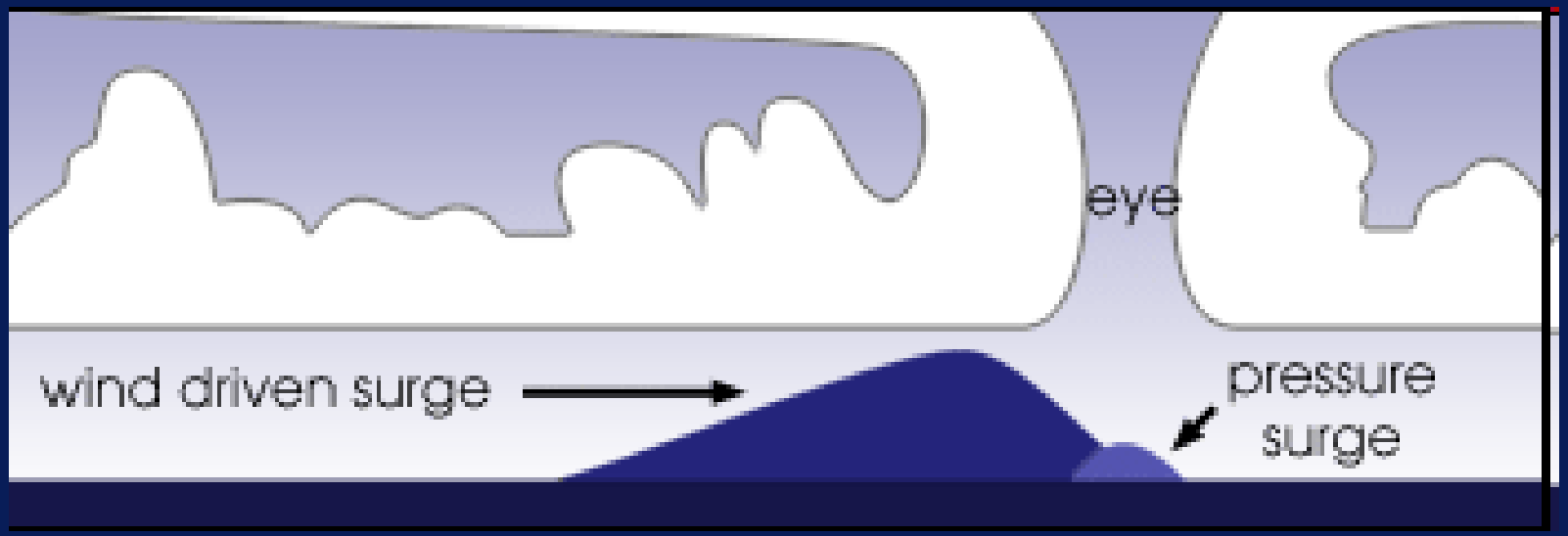
A. Pressure Surge



Pressure Surge - The light blue bulge represents to water surface increase due to the reduced pressure in the eye of the storm.

ANALOGY - if several people sit around the edge of a waterbed, the center of the bed rises!

B. Wind Surge

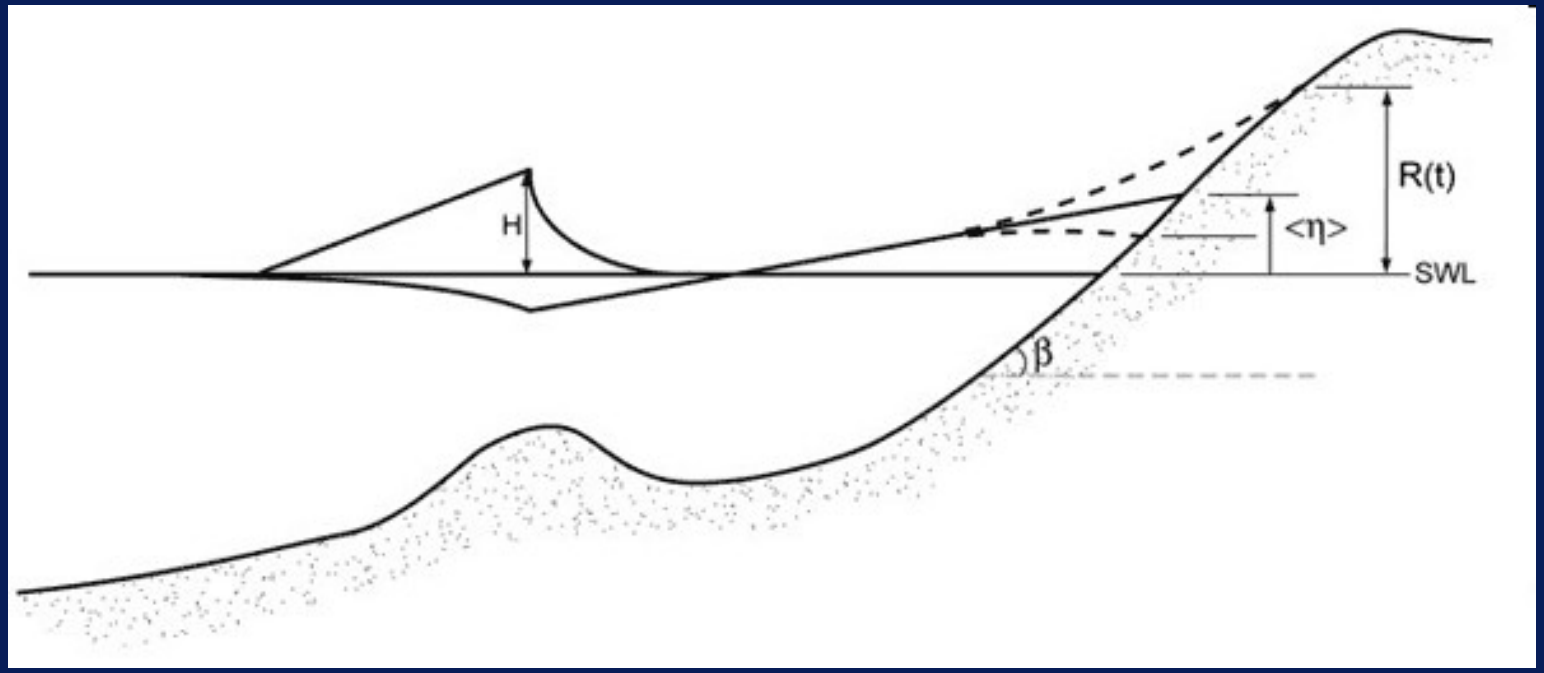


- **Surface stress (due to the wind) is balanced by a water surface slope.**

ANALOGY - blowing on a hot cup of coffee.!

- **Wind surge becomes more pronounced in shallow water.**

C. Wave Setup



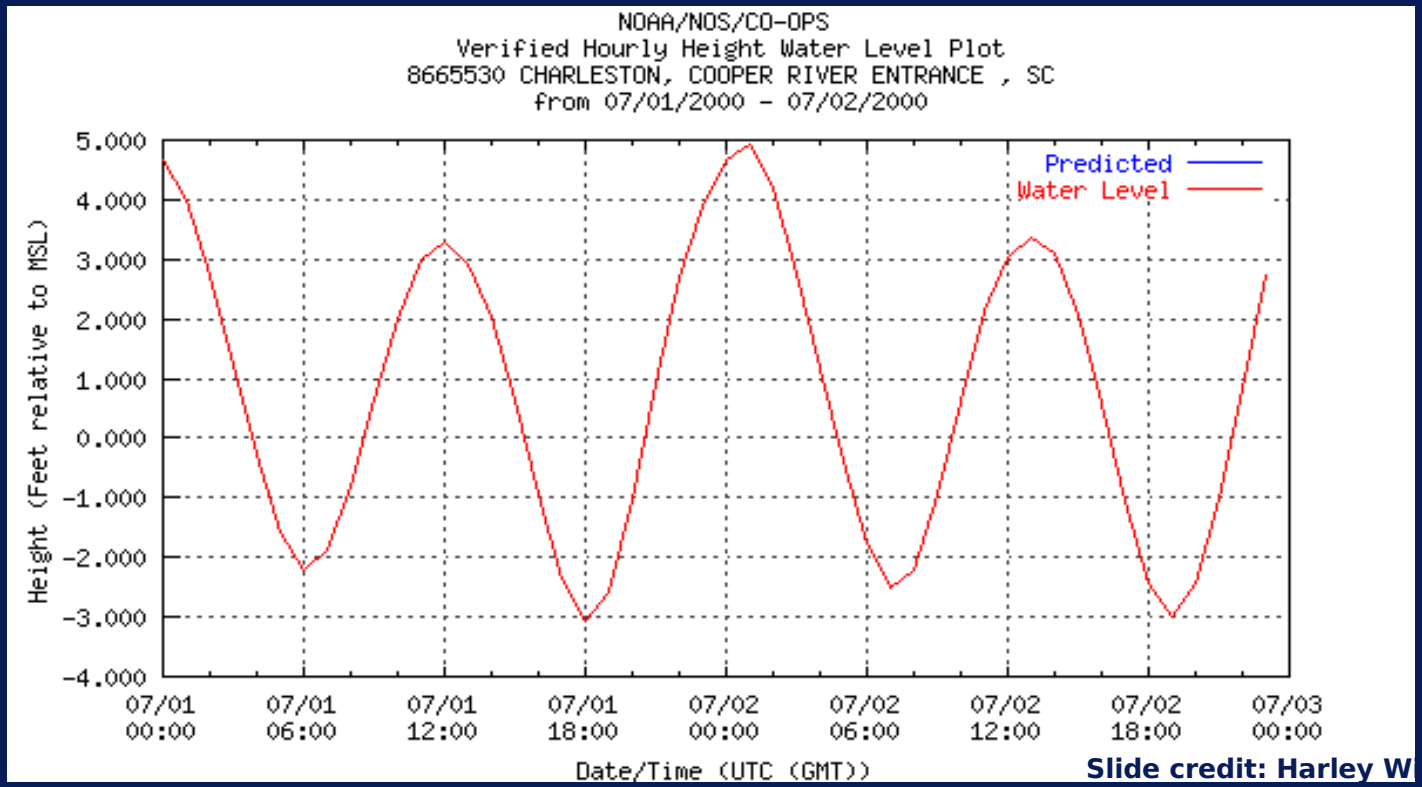
This gradient of the S_{xx} radiation stress term is balanced by a slope of the water surface.

From linear wave theory, it can be shown that the mean water level at the shoreline is elevated by more than 20% of the wave height.

5. Timing (Tide)

Assume Category 2 Hurricane or 8 foot surge

Compare peak at 18:00 July 1 vs. 01:00 July 2

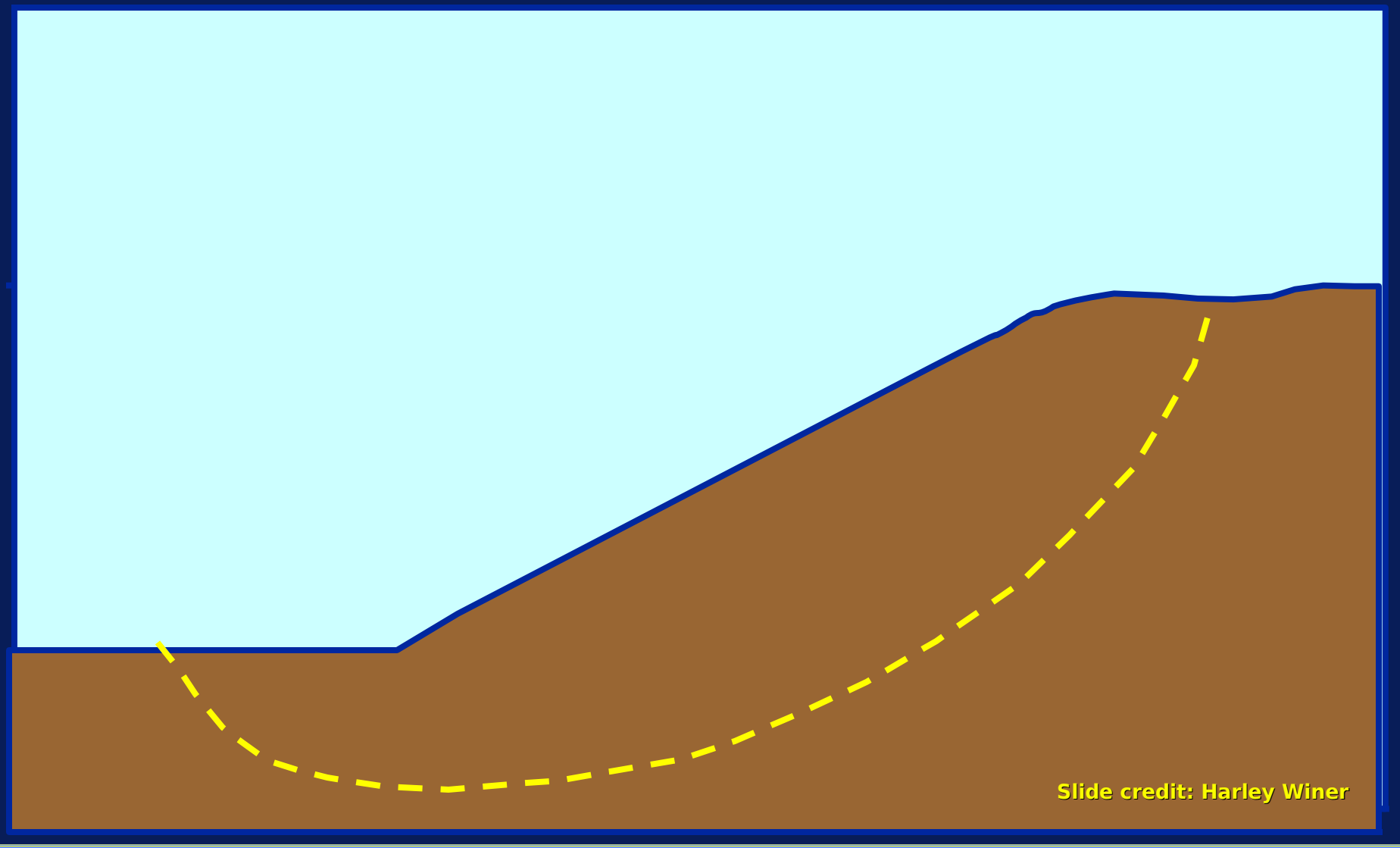


Slide credit: Harley W

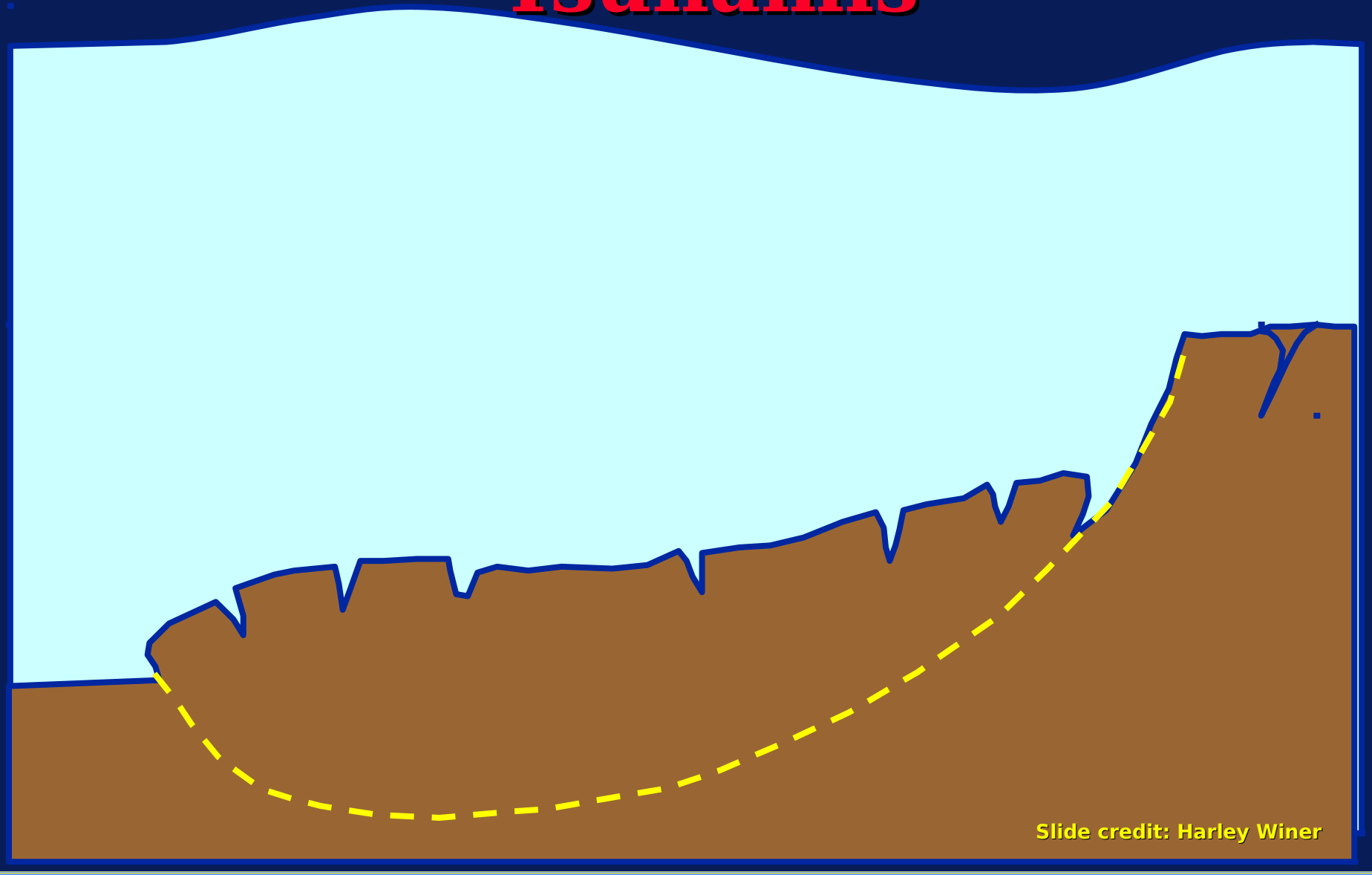
Pacific Coast

- **Tsunamis** is Japanese for “Big Wave.”
- **Tsunamis** can be earthquake or landside Induced.
- **Tsunamis** considered long period or shallow water wave.
- **Tsunamis** has small amplitude in deep ocean and shoals to great heights near shore.

Tsunamis



Tsunamis



Coastal Processes

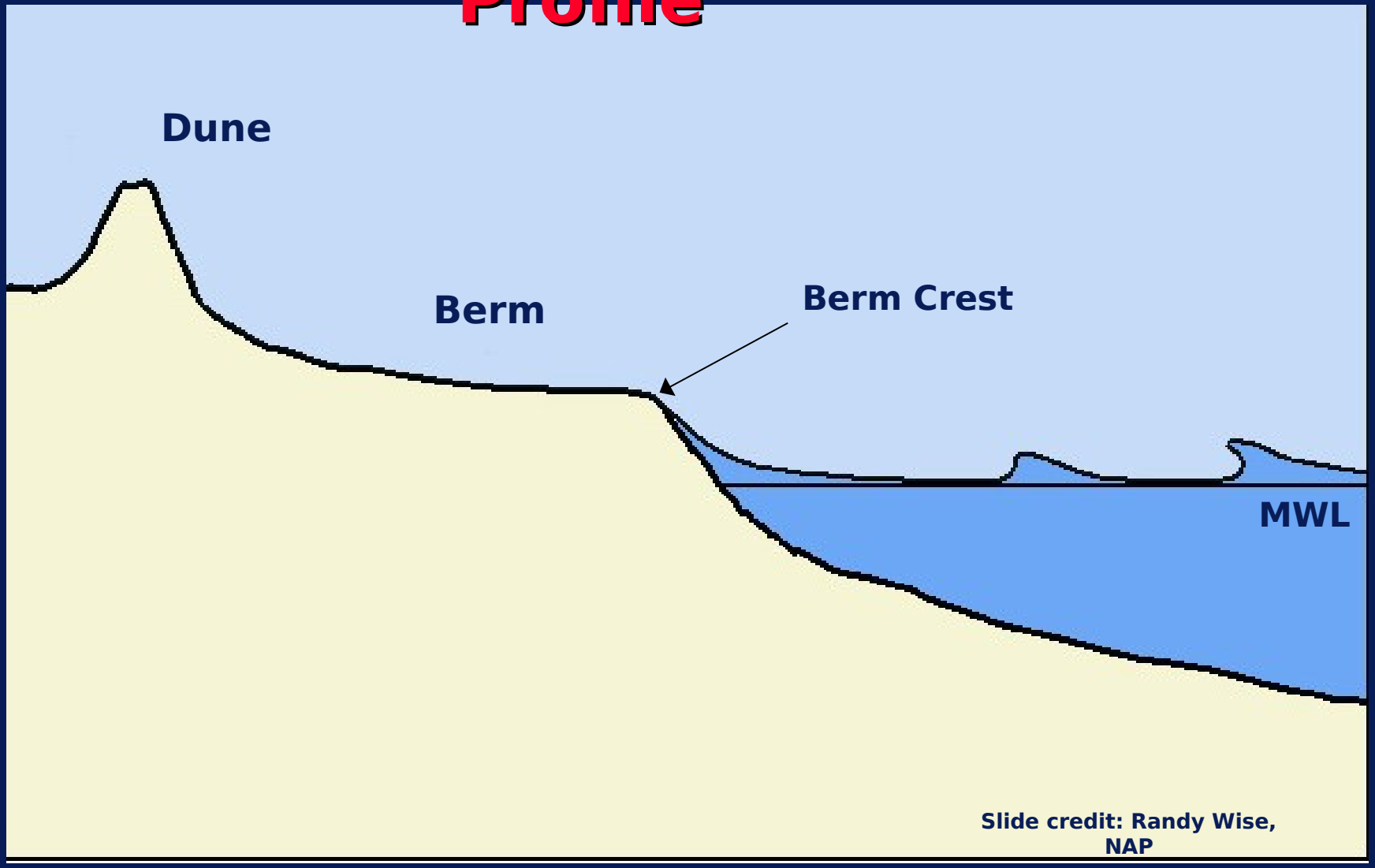
Beach profiles

Littoral transport (cross-shore and longshore)

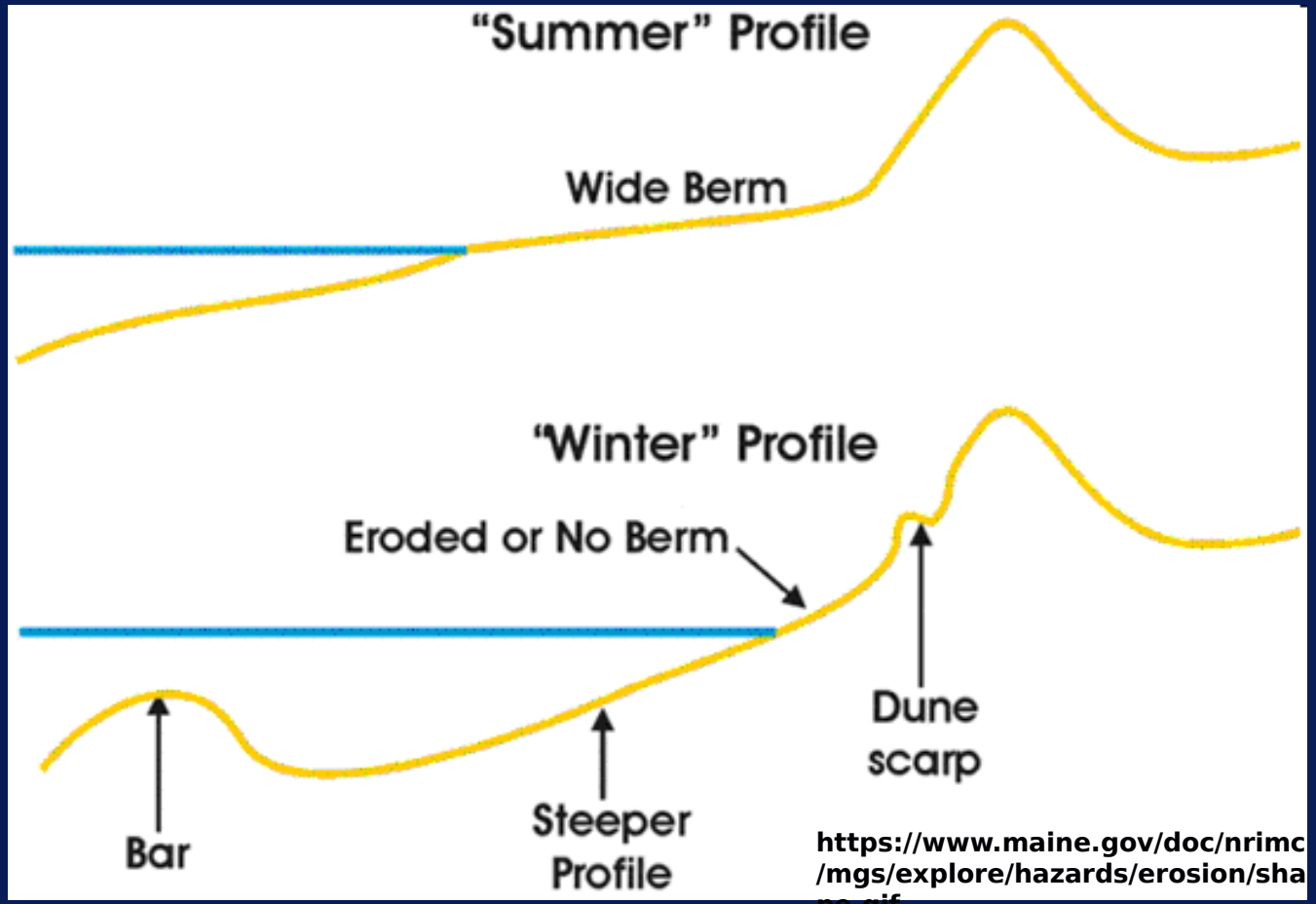
Sediment budgets

Accretion/Erosion

Beach Profile

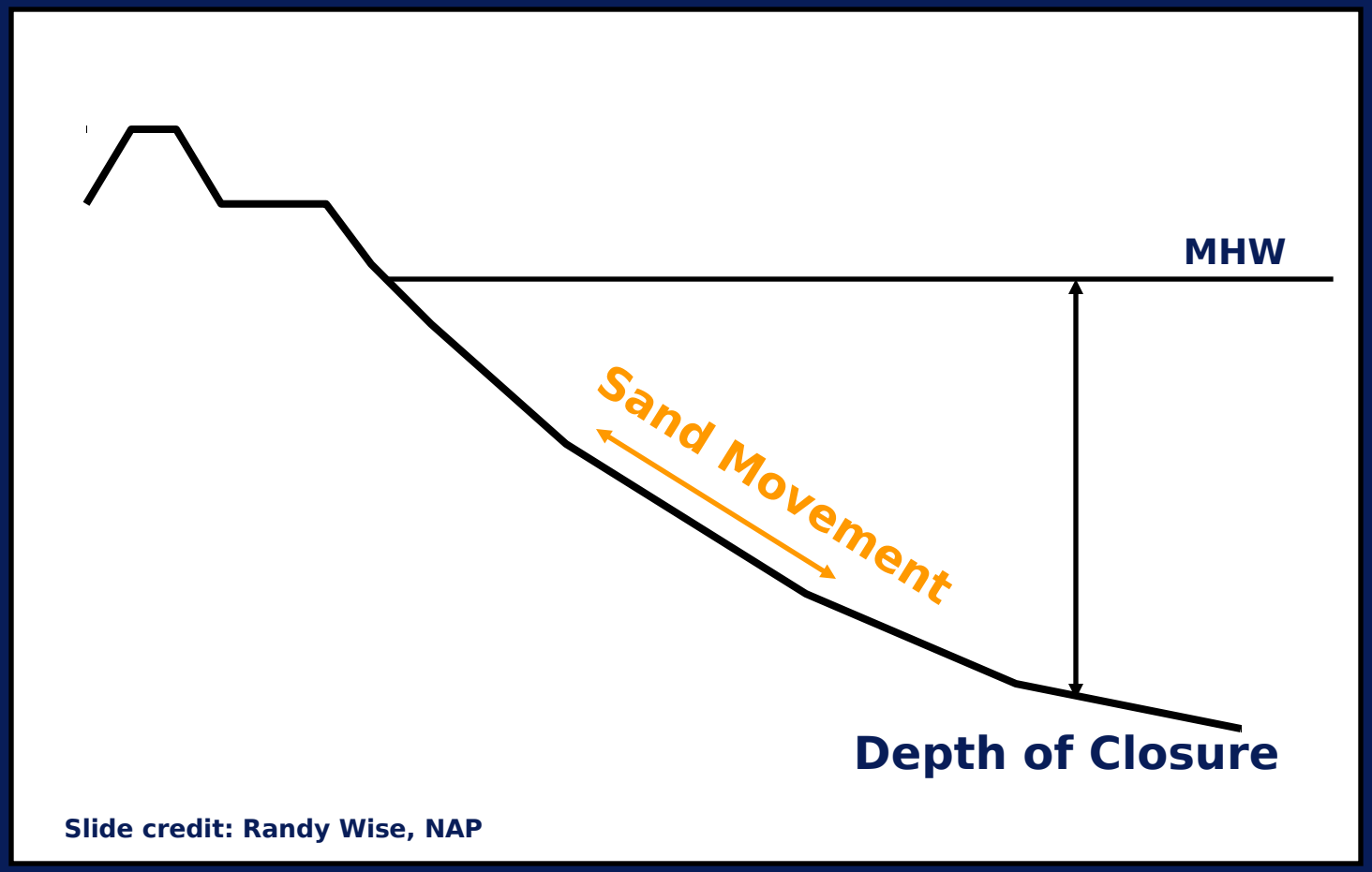


Seasonal Profiles



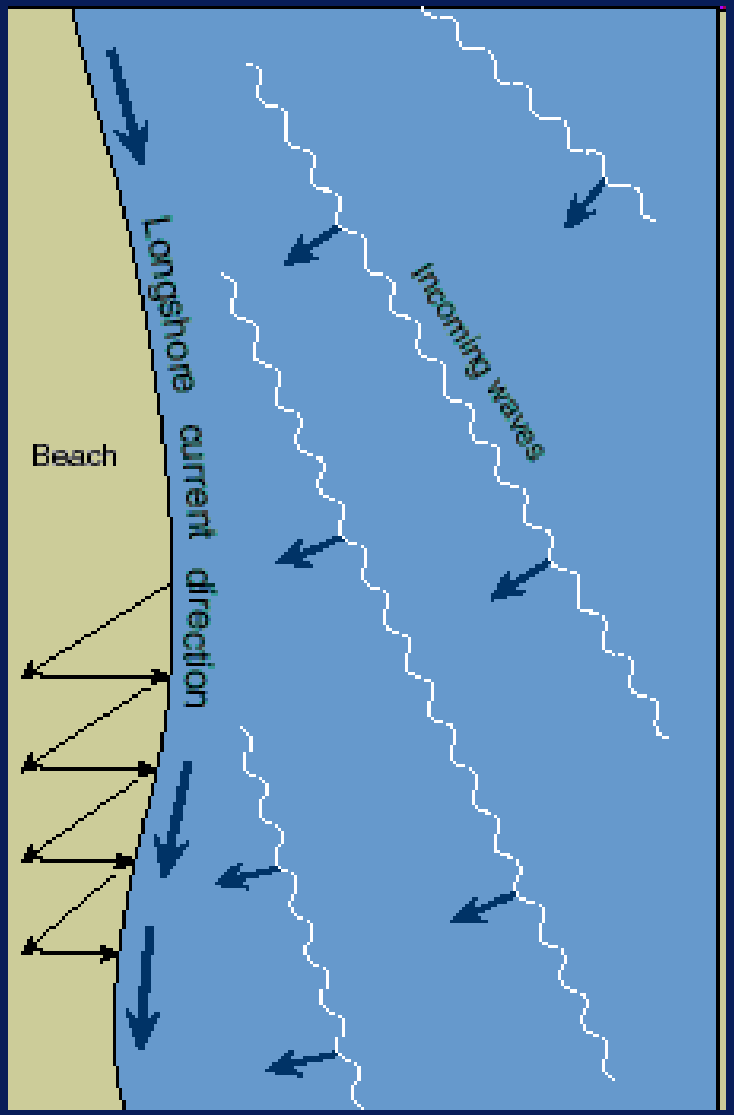
https://www.maine.gov/doc/nrimc/mgs/explore/hazards/erosion/shape.gif

Cross-shore transport



Slide credit: Randy Wise, NAP

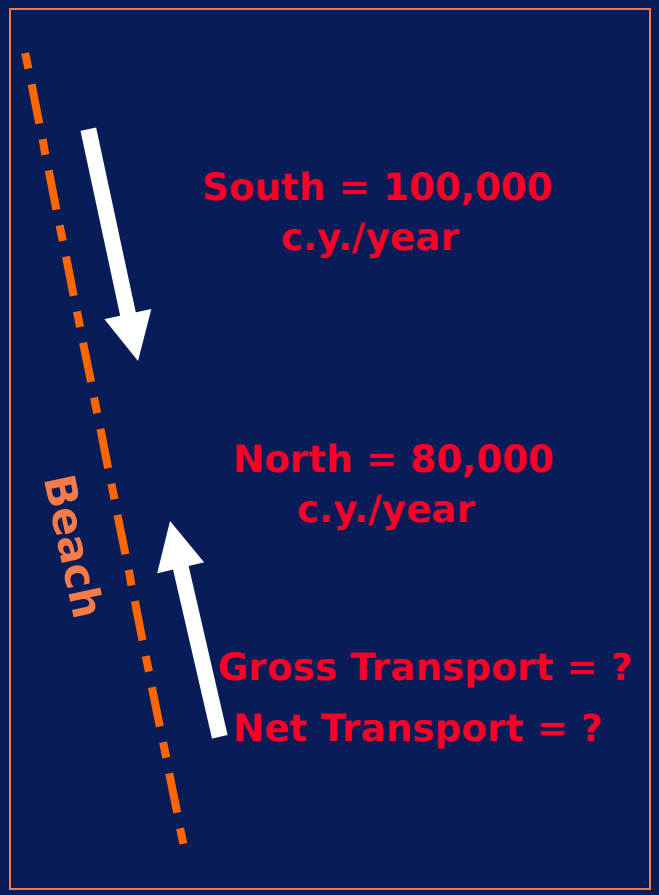
Longshore transport



http://pubs.usgs.gov/circ/c1075/images/longshore.gif

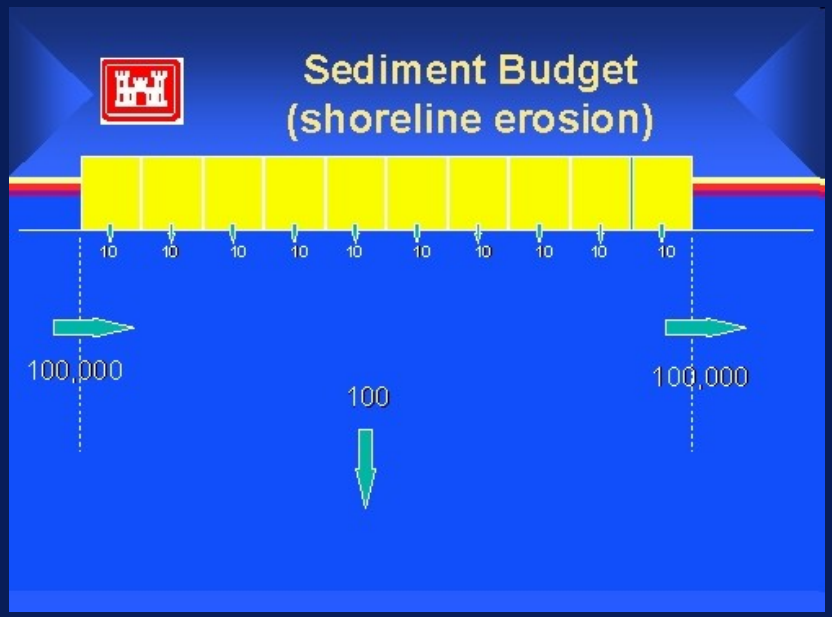
Sediment Budgets

- Generally waves come from a predominate direction, so net transport will generally be in that direction
- Gross transport is the sum of the transport in the two directions
- Net transport is the difference between the transport in the two directions



Sediment Budgets

- It is important to identify rates of erosion when building on the coast. A beach can remain in equilibrium if the incoming sediment matches outgoing sediment.
- Empirical equations estimate longshore transport.
- Conservation of mass (check book analogy)
  - when outgoing is greater than incoming - erosion
  - when incoming is greater than outgoing – accretion



Accretion/Erosion

Sources (+)

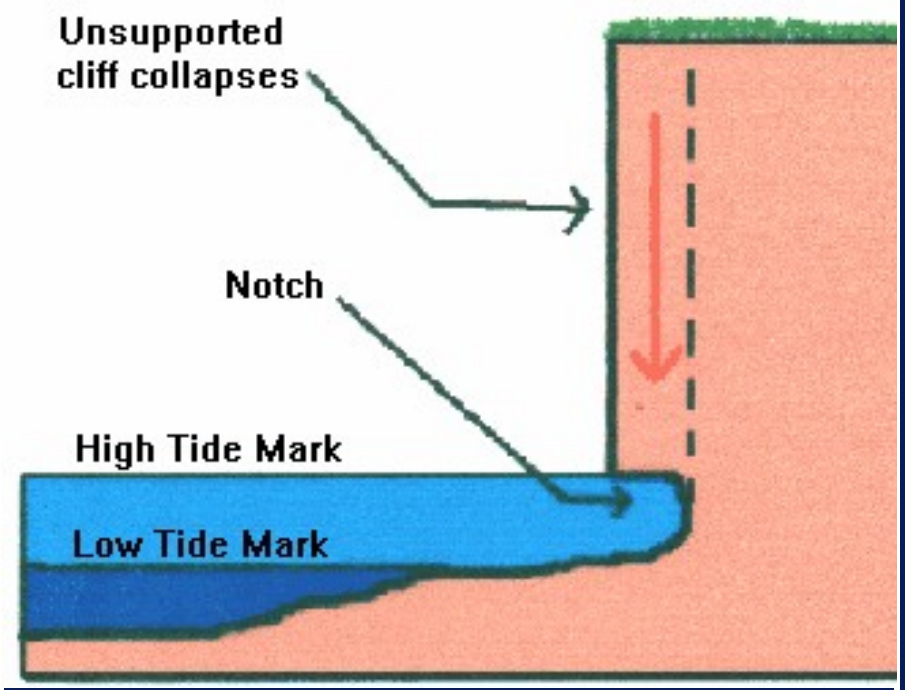
- Rivers
- Eroding headlands

Sinks (-)

- Sediment Traps
- Inlets
- Offshore Depths
- Littoral Drift Interruptions
- Sea Level Rise

Sources (+)

Eroding Headland

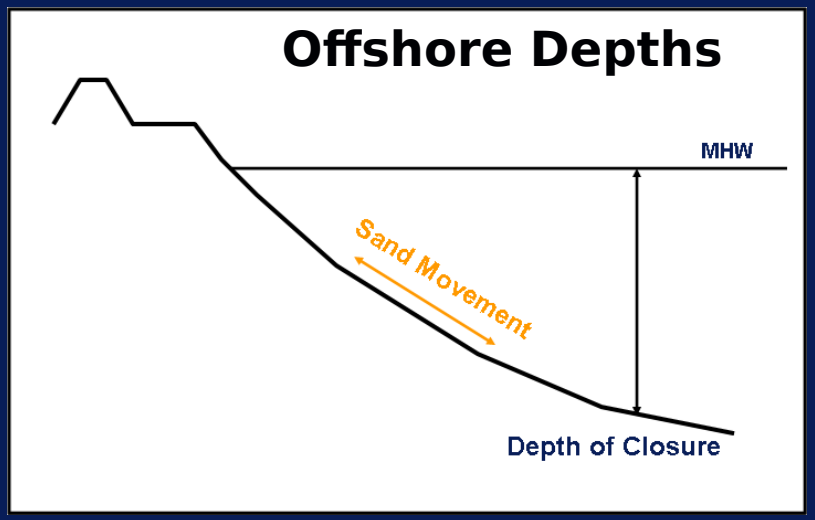


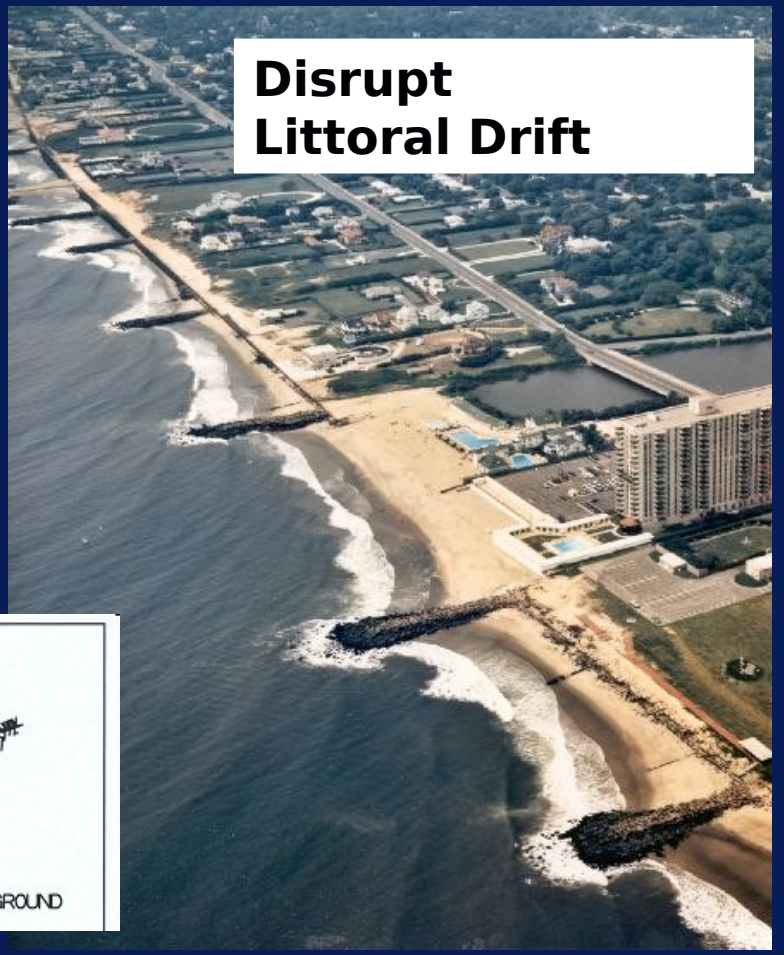
River Delta

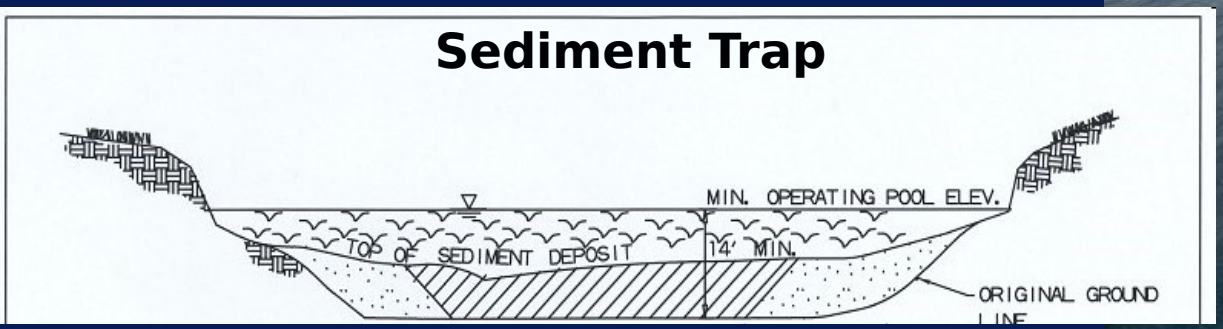
Sinks

Tidal Inlets - Canaveral, Fl

Sinks







www.nww.usace.army.mil/dmmp/report.htm

Sinks

Implications of Sea Level Rise

- Absolute Sea Level Rise
- Relative Sea Level Rise – i.e. subsidence (land sinking)
- Adjustment of Equilibrium Beach Profile
- Sea level rise will be very significant in the evaluation of future with and future without project conditions.

Summary

In this session, we have:

1. **Defined Coastal Engineering**
2. **Introduced common vocabulary used by coastal scientists and engineers.**
3. **Explained some of the similarities and differences between the principal US coastal regions.**
4. **Provided an overview of the important physical processes in the coastal zone.**